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Application No.	Country of Origin	Filed
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Respectfully submitted,

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Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

00306022.5

Der Präsident des Europäischen Patentamts;
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Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

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Purge gas for use in lithographic apparatus

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Bemerkungen:
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Remarques:

Purge Gas for use in Lithographic Projection Apparatus

The invention relates to the use of purge gas in a lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table provided with a first object holder for holding a mask;

a second object table provided with a second object holder for holding a substrate; and

a projection system for imaging an irradiated portion of said mask onto a target portion of said substrate.

For the sake of simplicity, the projection system may hereinafter be referred to as the "lens"; however, this term should be broadly interpreted as encompassing various types of projection system, including refractive optics, reflective optics, and catadioptric systems, for example. The illumination system may also include elements operating according to any of these principles for directing, shaping or controlling the projection beam, and such elements may also be referred to below, collectively or singularly, as a "lens". In addition, the first and second object tables may be referred to as the "mask table" and the "substrate table", respectively.

Lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the mask (reticle) may contain a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto a target portion (comprising one or more dies) of a substrate (silicon wafer) which has been coated with a layer of radiation sensitive material (resist). In general, a single wafer will contain a whole network of adjacent target portions which are successively irradiated via the reticle, one at a time. In one type of lithographic projection apparatus, each target portion is irradiated by exposing the entire reticle pattern onto the target portion in one go; such an apparatus is commonly referred to as a wafer stepper. In an alternative apparatus — which

is commonly referred to as a step-and-scan apparatus — each target portion is irradiated by progressively scanning the reticle pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or anti-parallel to this direction; since, in general, the projection system will have a magnification factor M (generally < 1), the speed V at which the substrate table is scanned will be a factor M times that at which the reticle table is scanned. More information with regard to lithographic devices as here described can be gleaned from International Patent Application WO97/33205, for example.

In general, lithographic apparatus contain a single mask table and a single substrate table. However, machines are becoming available in which there are at least two independently movable substrate tables; see, for example, the multi-stage apparatus described in International Patent Applications WO98/28665 and WO98/40791. The basic operating principle behind such multi-stage apparatus is that, while a first substrate table is at the exposure position underneath the projection system for exposure of a first substrate located on that table, a second substrate table can run to a loading position, discharge a previously exposed substrate, pick up a new substrate, perform some initial measurements on the new substrate and then stand ready to transfer the new substrate to the exposure position underneath the projection system as soon as exposure of the first substrate is completed; the cycle then repeats. In this manner it is possible to increase substantially the machine throughput, which in turn improves the cost of ownership of the machine. It should be understood that the same principle could be used with just one substrate table which is moved between exposure and measurement positions.

To reduce the size of features that can be imaged, it is desirable to reduce the wavelength of the illumination radiation. Wavelengths of less than 180nm are therefore employed, for example 157nm or 126nm. However, such wavelengths are strongly absorbed by normal atmospheric air leading to unacceptable loss of intensity as the beam traverses the apparatus. In order to solve this problem, it has previously been proposed to flush the apparatus with a flow of gas, the gas being substantially transparent to the illumination wavelength, e.g. nitrogen (N_2).

Lithographic projection apparatus may comprise interferometric displacement measuring means which are used to accurately determine the position of movable mask or substrate tables. These means measure the optical path length (geometrical distance x refractive index) to the movable tables using measurement beams of coherent monochromatic radiation. The measuring means are very sensitive to variations in the refractive index of the medium that the measurement beams traverse through. In order to keep the measuring means operating to the high degree of accuracy that is required, any variation from the refractive index of said medium must be avoided.

Some spaces of the projection apparatus may be flushed with a purge gas in order to remove any gas, such as oxygen or water, which absorbs radiation at the wavelength of the projection beam of radiation. The inventors have found that if the gas used to purge the system enters the area where the interferometric displacement measuring means operate, the refractive index in these areas changes and the position measurements are affected.

It is an object of the invention to provide a lithographic projection apparatus in which escapage of the purge gas does not influence the interferometric displacement measuring means.

According to the invention there is provided a lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table provided with a first object holder for holding a mask;

a second object table provided with a second object holder for holding a substrate; wherein at least one of said first and second object tables is movable;

an interferometric displacement measuring means for measuring the position of said movable object table; and

a projection system for imaging an irradiated portion of said mask onto a target portion of said substrate; characterized by:

flushing gas means for supplying purge gas to a space, to displace therefrom ambient air, said space accommodating at least a part of said movable object table, wherein said purge gas is substantially non-absorbent of said projection beam of radiation and has a refractive index which is substantially the same as that of air when measured at the same temperature and pressure and using radiation of the same wavelength.

The inventors have found that by flushing the mask and substrate stages, comprising the mask and substrate tables respectively, with a specific gaseous composition, which has a refractive index identical to that of air under the same measuring conditions, the interferometric displacement measuring means are able to operate to the required degree of accuracy, whilst permitting the use of radiation having a wavelength of 180nm or less.

The invention also relates to a method of manufacturing a device using a lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table provided with a first object holder for holding a mask;

a second object table provided with a second object holder for holding a substrate; wherein at least one of said first and second object tables is movable;

an interferometric displacement measuring means for measuring the position of said movable object table; and

a projection system for imaging irradiated portions of said mask onto target portions of said substrate; the method comprising the steps of:

providing a mask bearing a pattern to said first object table;

providing a substrate provided with a radiation-sensitive layer to said second object table;

using said interferometric displacement measuring means to measure the position of said movable object table;

irradiating portions of the mask and imaging said irradiated portions of the mask onto said target portions of said substrate; characterized by the step of:

providing purge gas to a space accommodating at least a part of said movable object table to displace therefrom ambient air, and wherein said purge gas is substantially non-absorbent of said projection beam of radiation and has a refractive index which is substantially the same as that of air when measured at the same temperature and pressure and using radiation of the same wavelength.

In a manufacturing process using a lithographic projection apparatus according to the invention a pattern in a mask is imaged onto a substrate which is at least partially covered by a layer of radiation-sensitive material (resist). Prior to this imaging step, the substrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be subjected to other procedures, such as a post-exposure bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping), metallization, oxidation, chemo-mechanical polishing, etc., all intended to finish off an individual layer. If several layers are required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices (dies) will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4.

Although specific reference may be made in this text to the use of the apparatus according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic *heads*, *etc.*

The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "exposure area" or “target portion”, respectively.

The radiation used as the projection beam should not be seen as being restricted to the cited examples of radiation having a wavelength of 157nm or 126nm; it is conceivable that other wavelengths or types may also be used in the present invention.

The invention and its attendant advantages will be further described below with reference to exemplary embodiments and the accompanying schematic drawings, whereby:

Figure 1 depicts a lithographic projection apparatus according to a first embodiment of the invention;

Figure 2 shows the mask stage of the lithographic projection apparatus of Fig. 1 in more detail; and

Figure 3 depicts the substrate stage of the lithographic projection apparatus of Fig. 1 in more detail.

In the drawings, like parts are identified by like reference numerals.

Figure 1 schematically depicts a lithographic projection apparatus according to the invention. The apparatus comprises:

- a radiation system LA, IL (Ex, IN, CO) for supplying a projection beam PB of radiation (e.g. UV or EUV radiation);
- a first object table (mask table) MT provided with a mask, or first object, holder for holding a mask MA (e.g. a reticle), and connected to first positioning means for accurately positioning the mask with respect to item PL;
- a second object table (substrate or wafer table) WT provided with a substrate, or second object, holder for holding a substrate W (e.g. a resist-coated silicon wafer), and

connected to second positioning means for accurately positioning the substrate with respect to item PL;

- a projection system ("lens") PL (e.g. a refractive or catadioptric system or a mirror group) for imaging an irradiated portion of the mask MA onto an exposure area C (target portion) of a substrate W held in the substrate table WT.

As here depicted, the apparatus is of a transmissive type (i.e. has a transmissive mask). However, in general, it may also be of a reflective type, for example.

The radiation system includes a source LA (e.g. an Hg lamp or an excimer laser) which produces a beam of UV radiation. This beam is passed along various optical components comprised in the illumination system IL — e.g. beam shaping optics Ex, an integrator IN and a condenser CO — so that the resultant beam PB has a desired shape and intensity distribution in its cross-section.

The beam PB subsequently intercepts the mask MA, which is held in a mask holder on a mask table MT. Having passed through the mask MA, the beam PB passes through the lens PL, which focuses the beam PB onto an exposure area C of the substrate W. With the aid of the interferometric displacement measuring means IF, the substrate table WT can be moved accurately by the second positioning means, e.g. so as to position different exposure areas C in the path of the beam PB. Similarly, the first positioning means can be used to accurately position the mask MA with respect to the path of the beam PB, e.g. after mechanical retrieval of the mask MA from a mask library. In general, movement of the object tables MT, WT will be realized with the aid of a long-stroke module (course positioning) and a short-stroke module (fine positioning), which are not explicitly depicted in Figure 1. In the case of a waferstepper (as opposed to a step-and-scan apparatus) the reticle table may be connected only to a short-stroke positioning device, to make fine adjustments in mask orientation and position.

The depicted apparatus can be used in two different modes:

1. In step-and-repeat (step) mode, the mask table MT is kept essentially stationary, and an entire mask image is projected in one go (i.e. a single "flash") onto an

exposure area C. The substrate table WT is then shifted in the X and/or Y directions so that a different exposure area C can be irradiated by the beam PB;

2. In step-and-scan (scan) mode, essentially the same scenario applies, except that a given exposure area C is not exposed in a single "flash". Instead, the mask table MT is movable in a given direction (the so-called "scan direction", e.g. the X direction) with a speed v, so that the projection beam PB is caused to scan over a mask image; concurrently, the substrate table WT is moved in the same or opposite direction at a speed V = Mv, in which M is the magnification of the lens PL (typically, M = 1/4 or 1/5). In this manner, a relatively large exposure area C can be exposed, without having to compromise on resolution.

Figure 2 shows the mask stage, comprising mask table MT, of the lithographic apparatus according to the invention in more detail.

It will be seen that the mask M is held in a recess in mask table MT, which can be manufactured from a ceramic material such as Zerodur (RTM) and is positioned by a drive system (not shown) during operation of the lithographic apparatus. The mask table MT is closely sandwiched between the last element of the collimating optics CO, which generate the projection beam PB, and the first element of the projection lens system PL, which projects the projection beam PB, having passed through the mask M, onto the wafer W (shown in figures 1 and 3).

The mask stage may be divided into zones or spaces 2 to 6 as follows: space 2 is between the final illuminator optics CO and mask table MT; space 3 is within the mask table MT above the mask M; space 4 is within the mask table MT, between the mask M and pellicle 13; space 5 is within the mask table MT below the pellicle 13; and space 6 is between the mask table MT and projection lens system PL. Each of the spaces is flushed with a purge gas provided from gas supply 11 via respective flow regulators 112 to 116. At the other side of each space the purge gas is removed to reservoir 12 via respective vacuum pumps 122 to 126. Reservoir 12 may be partitioned to allow controlled re-use of the gas in selected spaces and may included devices 12a to clean or scrub the recovered gas.

If desired, the various spaces in the mask stage can be separated from one another to ensure laminar flow. For example, a thin sheet 14, e.g. of CaF or fused SiO_2, may be provided to cover the recess in the mask table MT and separate space 2 from space 3. Similarly, sheets 15 and 16 may be used to separate spaces 5 and 6, and to cover the non-flat surface of the first element of the projection lens system PL, respectively.

To supply and remove the gas flow to spaces 3, 4 and 5, within the mask table MT, appropriate conduits are provided in the body of the mask table. When the mask table has been exposed to air, e.g. after a period of non-operation of the apparatus or after mask exchange, purge gas is supplied for a short period before an exposure is taken to flush out any air that may have accumulated, e.g. in non-flat parts of the mask table.

Figure 3 shows the wafer stage of the lithographic apparatus of Figure 1. To avoid having to provide a purge gas path covering the entire range of movement of the wafer stage, the flushing gas supply outlets 17 and evacuation inlets 18 are mounted on the lower end of the projection lens system PL, either side of the final element. Outlets 17 and inlets 18 are respectively connected to the gas supply 11 and reservoir 12 via flow regulator 117 and vacuum pump 127 respectively. The outlets 17 in particular, but also the inlets 18, may be provided with vanes to guide the flow of purge gas. If not already flat, the final element of the projection lens system PL may be covered with a thin sheet as discussed above.

The flow regulators 112 to 117 mentioned above may comprise static or controllable pressure or flow reducers and/or blowers as required to provide the necessary gas flow rates for the particular embodiment and the available gas supply.

According to the invention, the mask stage and/or the substrate stage of the apparatus are flushed with a purge gas. The purge gas comprises a mixture of two or more gases selected from N_2, He, Ne, Ar, Kr and Xe. The gas composition used is one which is substantially transparent to UV radiation of the wavelength of the projection beam and has a refractive index which is substantially the same as that of air, when measured under the same conditions of temperature and pressure (e.g. standard clean room conditions) and using radiation of the same wavelength. The refractive index should be the same as that of

air at the wavelength of a radiation beam used in the interferometric displacement measuring means IF. The pressure of the purge gas in the mask and/or substrate stages may be atmospheric pressure, or it may be above atmospheric pressure so that any leak results in an outflow of gas rather than contaminating the system with incoming air.

To determine which mixtures of gases are suitable for use in the present invention, the refractive index of the mixture must be known. The refractive index n of a mixture of k gases at a specific partial pressure, temperature and wavelength can be determined using the following equation:

$$n - 1 = \sum_{i=1}^{k} C_i (n_i - 1)$$

or

$$n = \sum_{i=1}^{k} C_i n_i$$

where C_i is the relative volume concentration of the gas i, and n_i is the refractive index of the pure gas i. Thus, for the purposes of the present invention, if the purge gas consists of a mixture of gases x and y, the relative volume concentrations of the two gases must comply with the equation:

$$n_{air} = C_x n_x + C_y n_y$$

where n_{air} is the refractive index of air. Refractive indices are dependent on pressure, temperature and wavelength, thus all values of n in the above equations must relate to the same temperature, pressure and wavelength (the wavelength used for the calculations should be the same as that of at least one of the radiation beams of the interferometric displacement measuring means).

Suitable mixtures of gases which comply with this equation include mixtures comprising N_2 and either from 1 to 5 vol.% He, preferably from 2 to 3 vol.% He; from 1 to 5 vol.% Ne, preferably from 3.5 to 2.5 vol.% Ne; or from 35 to 50 vol.% Ar, preferably from 40 to 45 vol.% Ar; mixtures comprising Ar and from 1 to 5 vol.% Xe, preferably from 2 to 3 vol.% Xe; mixtures comprising Ar and from 5 to 10 vol.% Kr, preferably from 6 to 8 vol.% Kr; and mixtures comprising N_2, from 0.5 to 3 vol.% He and from 0.5 to 3 vol.% Xe. Preferred mixtures of gases include:

97.3 vol.% N_2 and 2.7 vol.% He

97.0 vol.% N_2 and 3.0 vol.% Ne

59.0 vol% N_2 and 41.0 vol% Ar

97.5 vol.% Ar and 2.5 vol.% Xe

92.9 vol.% Ar and 7.1 vol.% Kr.

Whilst we have described above specific embodiments of the invention it will be appreciated that the invention may be practiced otherwise than described. The description is not intended to limit the invention.

CLAIMS:

1. A lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table provided with a first object holder for holding a mask;

a second object table provided with a second object holder for holding a substrate; wherein at least one of said first and second object tables is movable;

an interferometric displacement measuring means for measuring the position of said movable object table; and

a projection system for imaging an irradiated portion of said mask onto a target portion of said substrate; characterized by:

flushing gas means for supplying purge gas to a space, to displace therefrom ambient air, said space accommodating at least a part of said movable object table, wherein said purge gas is substantially non-absorbent of said projection beam of radiation and has a refractive index which is substantially the same as that of air when measured at the same temperature and pressure and using radiation of the same wavelength.

2. Apparatus according to claim 1 wherein the purge gas comprises two or more gases selected from N_2, He, Ar, Kr, Ne and Xe.

3. Apparatus according to claim 2 wherein said purge gas comprises at least 95% by volume N_2 and at least 1% by volume He.

4. Apparatus according to claim 2 wherein said purge gas comprises at least 95% by volume Ar and at least 1% by volume Xe.

5. Apparatus according to claim 2 wherein said purge gas comprises at least 90% by volume Ar and at least 5% by volume Kr.

6. Apparatus according to claim 2, wherein said purge gas comprises at least 95% by volume N_2 and at least 1% by volume Ne.

7. Apparatus according to claim 2, wherein said purge gas comprises at least 50% by volume N_2 and at least 35% by volume Ar.

8. Apparatus according to claim 2 wherein said purge gas comprises at least 94% by volume N_2, at least 0.5% by volume He and at least 0.5% by volume Xe.

9. Apparatus according to any one of claims 1 to 8 wherein said flushing gas means comprises a supply of purge gas, a gas flow regulator for controlling the rate of flow of purge gas to the space comprising said part of said movable object table and evacuation means for removing purge gas from said space.

10. Apparatus according to claim 9 wherein said flow regulator comprises a flow restrictor.

11. Apparatus according to claim 9 or 10 wherein said flow regulator comprises a blower.

12. Apparatus according to any one of the preceding claims wherein said radiation of said projection beam has a wavelength less than about 180nm, preferably about 157 nm or 126 nm.

13. A method of manufacturing a device using a lithographic projection apparatus comprising:

an illumination system for supplying a projection beam of radiation;

a first object table provided with a first object holder for holding a mask;

a second object table provided with a second object holder for holding a substrate; wherein at least one of said first and second object tables is movable;

an interferometric displacement measuring means for measuring the position of said movable object table; and

a projection system for imaging irradiated portions of said mask onto target portions of said substrate; the method comprising the steps of:

providing a mask bearing a pattern to said first object table;

providing a substrate provided with a radiation-sensitive layer to said second object table;

using said interferometric displacement measuring means to measure the position of said movable object table;

irradiating portions of the mask and imaging said irradiated portions of the mask onto said target portions of said substrate; characterized by the step of:

providing purge gas to a space accommodating at least a part of said movable object table to displace therefrom ambient air, and wherein said purge gas is substantially non-absorbent of said projection beam of radiation and has a refractive index which is substantially the same as that of air when measured at the same temperature and pressure and using radiation of the same wavelength.

14. A device manufactured according to the method of claim 13.

15. A purge gas as defined in any one of claims 3 to 8.

ABSTRACT

Purge Gas for use in Lithographic Apparatus

A lithographic projection apparatus comprising:

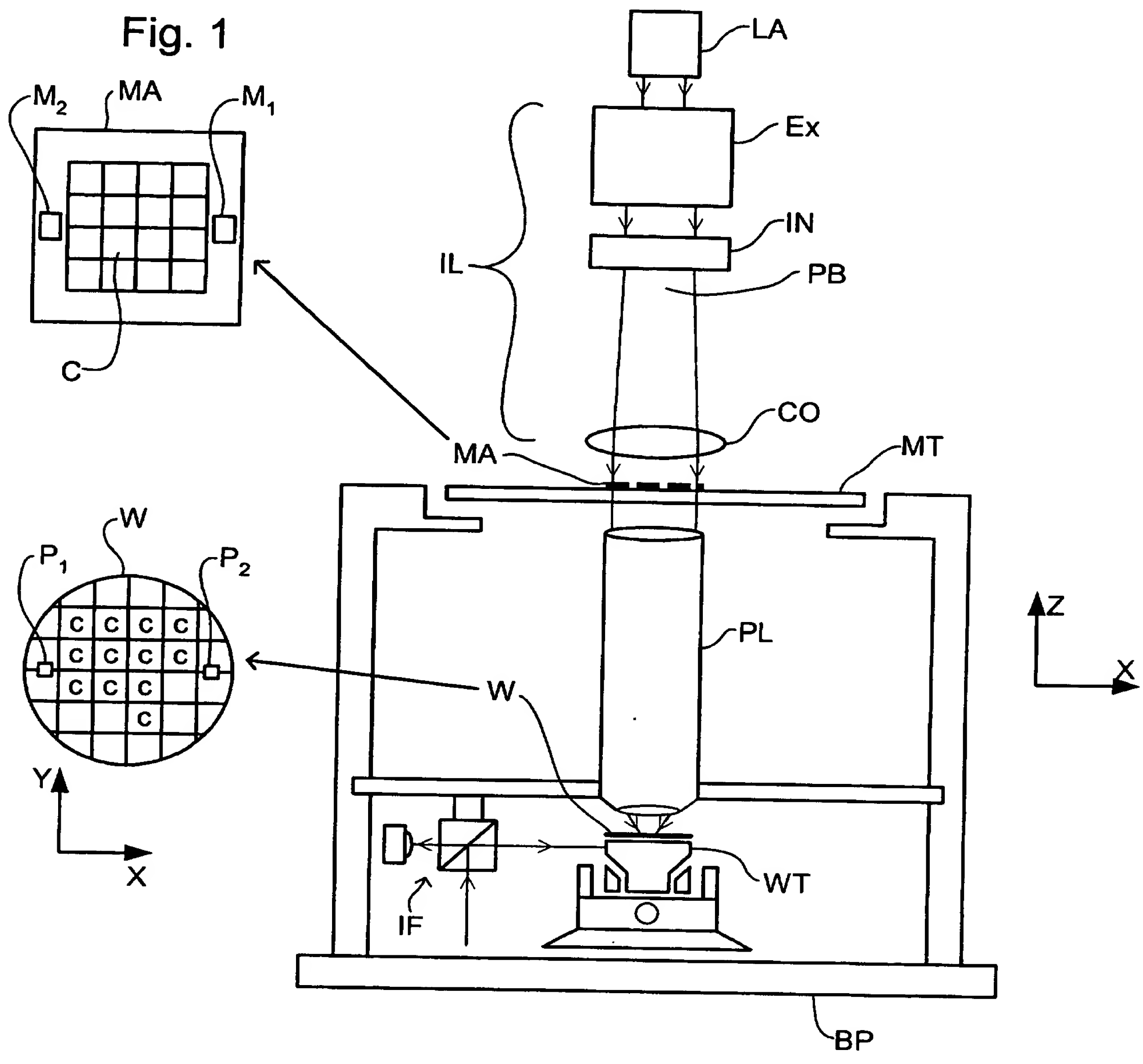
- an illumination system for supplying a projection beam of radiation;
- a mask stage comprising a mask table provided with a mask holder for holding a mask;
- a substrate stage comprising a substrate table provided with a substrate holder for holding a substrate;
- a projection system for imaging an irradiated portion of the mask onto a target portion of the substrate,

wherein a space accommodating at least a part of the mask stage and/or a space accommodating at least a part of the substrate stage is provided with flushing gas means for supplying purge gas, said purge gas being substantially non-absorbent of said projection beam of radiation and having a refractive index which is substantially the same as that of air when measured at the same temperature and pressure and using radiation of the same wavelength.

Fig. 1

1 / 2

Fig. 1


M2
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MT
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P1
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Fig. 2

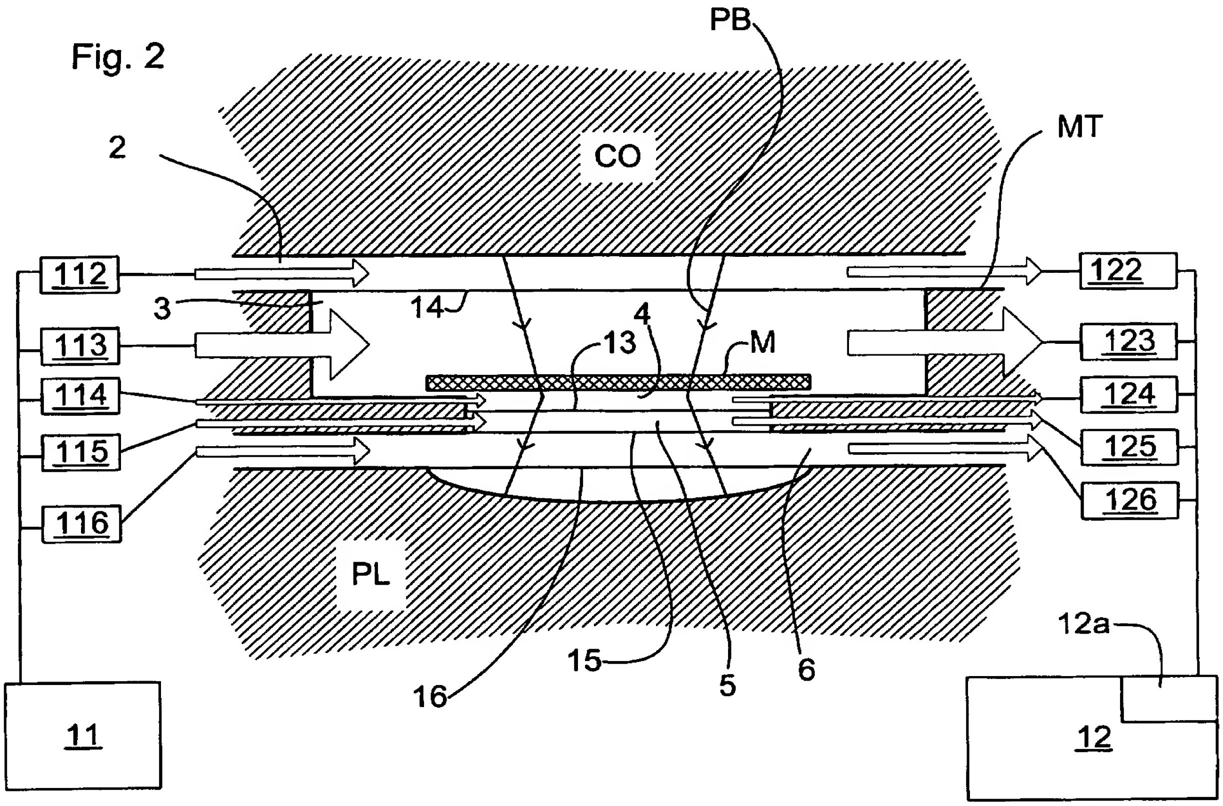
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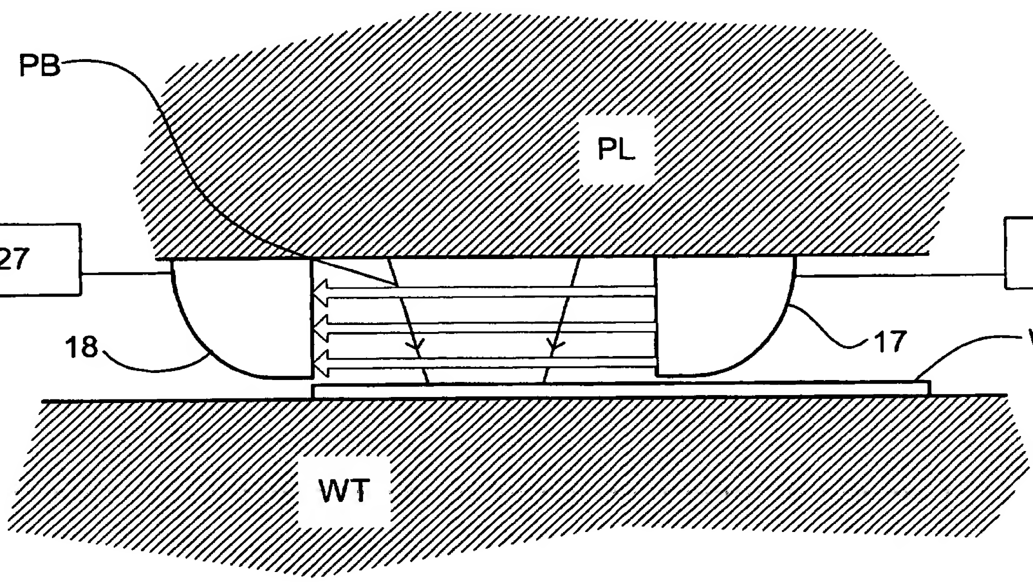
Fig. 3


PB
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18
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